Conference Paper

The PSD CBM supermodule response study for hadrons in momentum range 2 – 6 GeV/c at CERN test beams

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Abstract

The Projectile Spectator Detector (PSD) will be used at the Compressed Baryonic Matter (CBM) experiment at FAIR to measure the centrality and orientation of the reaction plane in heavy-ion collisions. A study of PSD supermodule response at proton and pion momentum range 2 – 6 GeV has been done at the CERN T10 beam line. The PSD supermodule is 3x3 array of 9 modules. Each module has transverse dimensions of 20x20 cm^2 and longitudinal dimension of 5.6 interaction lengths. The modules have sandwich structure of 60 lead/scintillator layers with the sampling ratio 4:1. Light from each scintillator plate is collected by a WLS fiber. Scintillator light from 6 consecutive scintillator plates (one longitudinal section) is detected by a 3x3 mm^2 Hamamatsu MPPC placed at the end of the module. In total, 10 MPPCs are used to detect light from 10 longitudinal sections in each module. Preliminary results on the longitudinal profile of energy deposition, linearity of the response and energy resolution of the supermodule are discussed.

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1. Introduction

The centrality and the reaction plane orientation in heavy ion collisions will be measured by the forward hadron calorimeters in the CBM and MPD experiments [1, 2] at the currently constructed acceleration facilities FAIR and NICA, respectively. The SIS100 accelerator at FAIR facility will accelerate Au nuclear beams up to an energy of 11 AGeV for experiments with a fixed target. The NICA collider is designed for Au beam energies $\sqrt{s}$=4–11.0 GeV in the center of mass system. Forward hadron calorimeters that are currently constructed for these experiments will measure mainly the energy of projectile spectators and the energy of produced particles near the beam axis. Due to the modular structure of calorimeters the coordinate information will be available for reaction plane determination. Similar hadron calorimeter is used now at NA61 experiment and its response has been studied at proton energies in the range of 20 - 150 GeV

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[3]. At present, the only experimental data on the energy resolution and the linearity of the single calorimeter module are available for the proton and pion energies in the range of 2 - 5 GeV [4]. Since the module's transverse size is only 20x20 cm^2, a significant lateral shower leakage would affect the energy resolution. Therefore, the response of the full hadron calorimeter must be comprehensively investigated at low proton and pion energies. For this purpose, the calorimeter supermodule with larger transverse sizes was constructed and tested at the T10 test beamline at CERN. First preliminary experimental results of calorimeter supermodule response at hadron momenta of 2–6 GeV/c are reported.

2. PSD CBM supermodule

A PSD supermodule consists of 9 individual modules with the transverse sizes of 20x20 cm^2 assembled in a 3x3 array as shown in Figure 1, left. The total longitudinal length of each module is 5.6 λ_I. The transverse size of the supermodule is 60x60 cm^2 that is enough to contain the most of the hadron shower inside the calorimeter. The total weight of the supermodule is about 4.5 tons. The structure of each module is shown in Fig. 1, right. The module consists of 60 lead-scintillator sandwiches with the sampling ratio 4:1. The thicknesses of the lead plates and scintillator tiles are 16 and 4 mm, respectively, that satisfies the compensation condition. Light readout is provided by WLS-fibers embedded in the grooves in the scintillator plates. It provides high efficiency and uniformity of the light collection in the scintillator tile. The WLS fibers from each 6 consecutive scintillator tiles are collected together and connected to a single photodetector at the end of the module. The longitudinal division into 10 sections ensures the uniformity of the light collection along the module. Ten Hamamatsu MPPCs S12572-010P are used as photodetectors in each module. The light yield measured with cosmic muons is about 50 ph.e per each section. More details about the PSD module design can be found in [1].

3. Experimental setup at the T10 beamline at CERN

The PSD supermodule response was studied at the T10 beamline of Proton Synchrotron (PS) at CERN. This beam line provides secondary beams of pions and protons with a momentum in the range of 2 – 6 GeV/c. To calibrate each PSD module with a muon beam, the supermodule was installed on a movable platform placed at the end of the T10 beam line (Fig. 2, left). The identification of beam particles was carried out by time

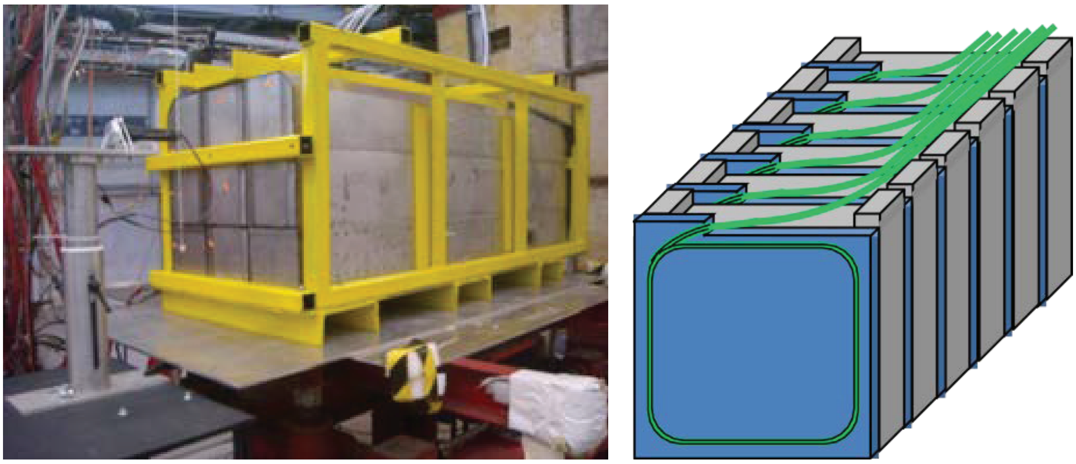

Figure 1: Photo of a PSD supermodule (left) and a schematic view of the PSD module structure (right).

of flight (TOF) measurements between two Cherenkov detectors. One of these detectors with a quartz radiator of a 30 mm diameter and the length of 30 mm was installed at the beam axis ahead of the front surface of the supermodule. Other Cherenkov detector with a quartz radiator of a 20 mm diameter and with the same length was placed upstream at a distance of about 12m from the supermodule. These detectors were readout by 12 bit 5 GS/s Switched Capacitor ADC model CAEN DT5742. The coincidence signal from both Cherenkov detectors triggered the data readout of the supermodule. Amplified and shaped MPPC signals were read out by two 64 channel 12-bit ADC64s boards, produced by AFI, JINR, Dubna. The time resolution of about 60 ps provided by Cherenkov detectors makes it possible to identify pions and protons in the full beam momentum range. The achieved TOF resolution enabled to measure the fraction of pions and protons for the T10 beam line for the first time (Fig. 2, right). As seen, the fractions of protons and pions with the highest momentum near 6 GeV/c are practically the same. While, the fraction of pions increases at the lower beam momenta.

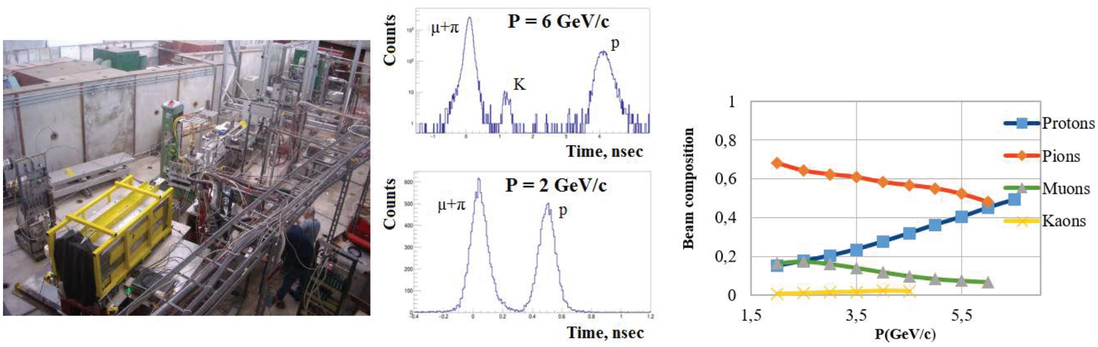

Figure 2: Left - photo of the PSD supermodule at the T10 beam line; Middle-TOF spectra for 2 and 6 GeV/c particles; Right - the fraction of particles in T10 beam as a function of the beam momentum.

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4. Energy calibration of the PSD supermodule

The energy calibration of all 10 sections in each of the 9 modules was performed by the muons contaminated in the T10 hadron beam. These muons are born in the in-flight decays of pion during the transportation through the beam line. The identification of muons was done using the two-dimensional correlation between the energy depositions in the first half of the module (first five sections) and the last half of the module (Fig. 3, left). These energy depositions for the muons should be practically the same, while the hadrons deposit main fraction of energy in the first half of the module. The muon energy depositions were measured in each of 10 module sections. The typical measured muon amplitude spectrum in one section is shown in Fig. 3, right. The mean value of the amplitude distribution corresponds to the muon energy loss of about 5 MeV in 6 layers of scintillators with the total thickness of 24 mm. The obtained calibration coefficients for all 90 sections of supermodule are used for the calculation of the energy depositions separately for pions and protons.

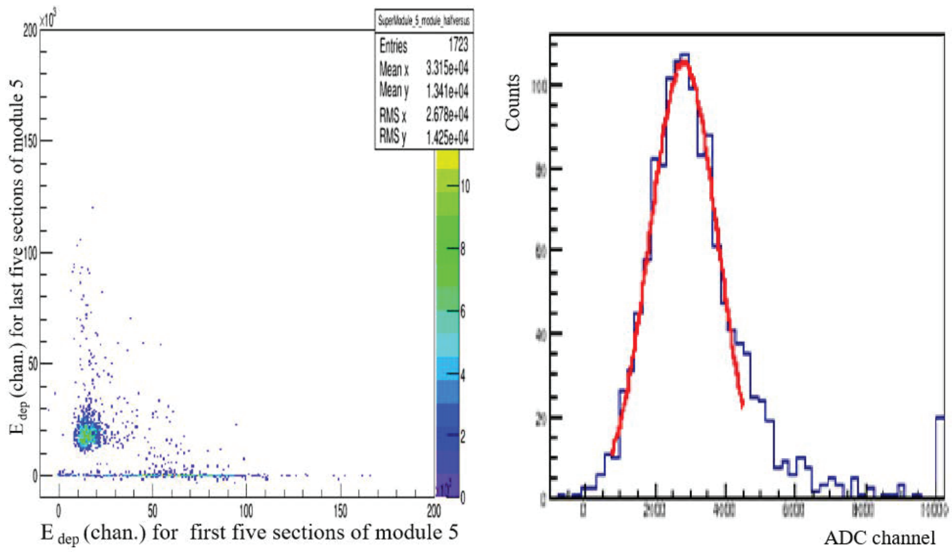

Figure 3: Left - the two-dimensional correlation between the energy depositions in the first half of the module (first five sections) and the last half of the module. Right -typical muon amplitude spectrum in one section of module.

5. Supermodule response to pions and protons

The supermodule response to hadrons was studied for the beam momentum range from 2 to 6 GeV/c with a step of 0.5 GeV/c separately for protons and pions. This momentum range corresponds to a kinetic energy range 1.27 - 5.14 GeV for protons and to 1.87 - 5.86 GeV for pions. Total energy deposition in all 9 modules of the PSD supermodule was measured for all these pion and proton energies. Examples of these distributions for particle momentum of 6 GeV/c are shown in Fig. 4. The left peak in the distribution of the pion energy deposition reflects the admixture of muons in the pion beam.

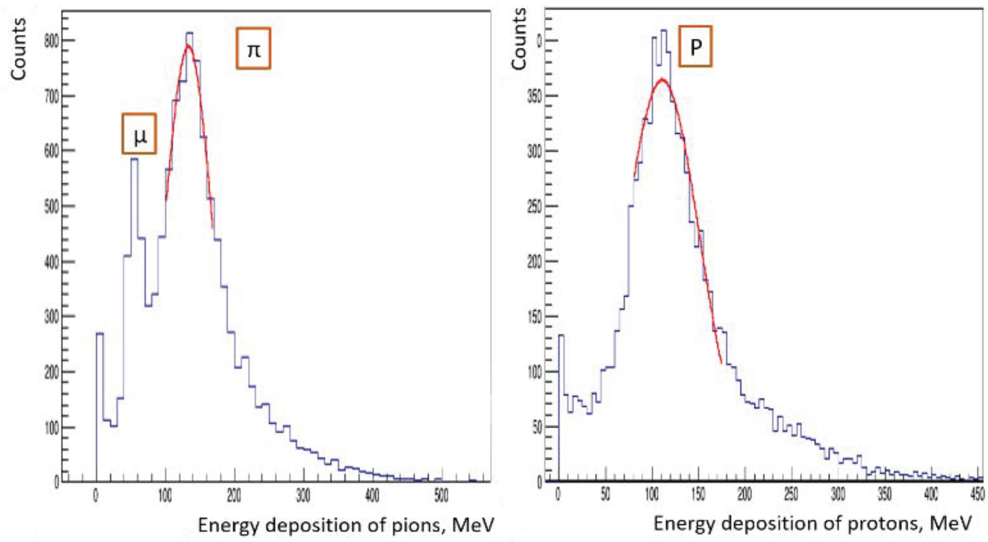

Figure 4: Spectra of total energy deposition in the PSD supermodule for pions (left) and protons (right) with the momentum of 6 GeV/c.

The longitudinal energy deposition profiles in the central module for pions and protons with the highest and lowest momenta are shown in Fig. 5. One can see, that for the beam momentum of 6 GeV/c the longitudinal profiles are rather similar for both pions and protons. The situation is quite different at the lowest beam momentum of 2 GeV/c, where an evident discrepancy for pion and proton profiles is observed. It can be explained by the different probabilities of proton/pion interactions during the hadron shower development along the module.

The energy resolutions and the linearity of the PSD supermodule response to protons and pions in momentum range of 2–6 GeV/*c* are presented in Fig. 6. It should be noted that energy resolution is practically the same for pions and protons with the momenta higher than 4 GeV/c. Therefore, for the higher momenta the response of supermodule can be studied without pion and proton identification.

6. Conclusions

Preliminary results of the PSD supermodule response measurements for pions and protons momenta in the range of 2 -6 GeV/c have been presented. The energy resolution of the supermodule is in good agreement with the resolution measured earlier

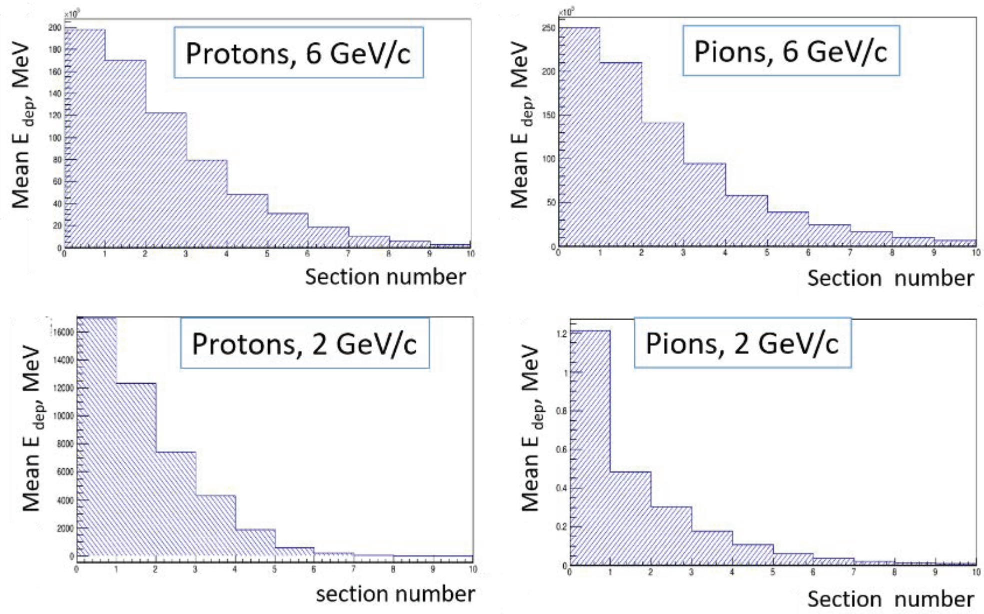

Figure 5: The longitudinal energy profile in the central module of the PSD supermodule for pions and protons with the momenta of 6 GeV/c (up) and 2 GeV/c (down).

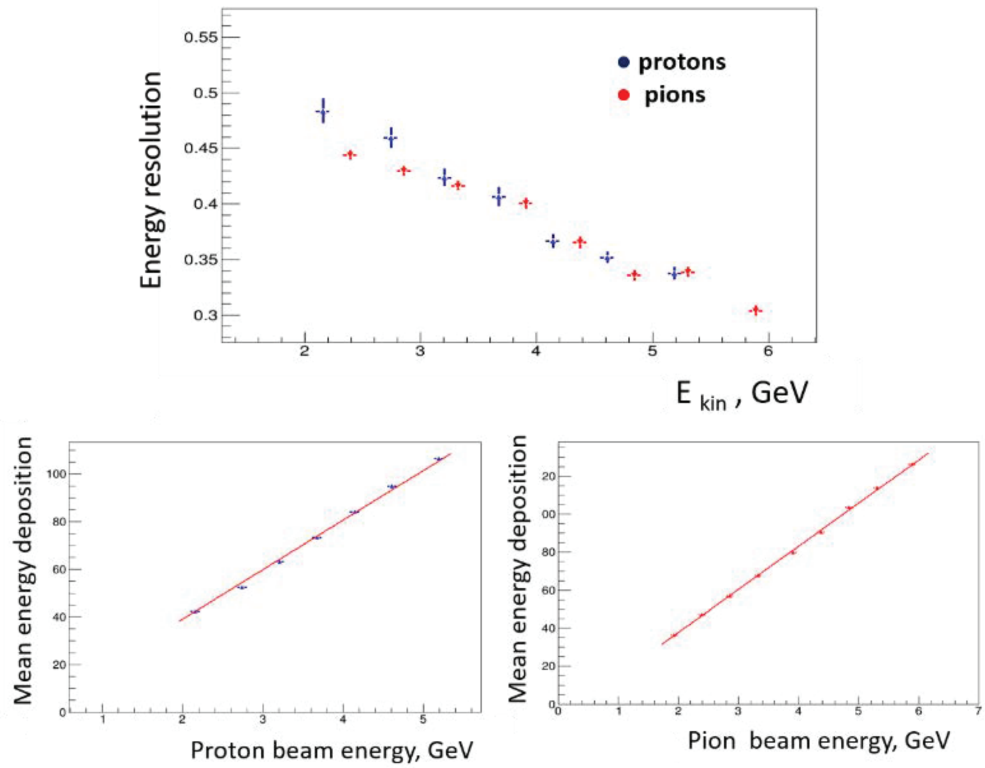

Figure 6: Energy resolution of the PSD supermodule for pions and protons as a function of particle energy (up) and the linearity of the supermodule response to protons (down left) and to pions (down right).

for a single module [4]. The results demonstrate that supermodule performance based on lead/scintillator sampling with the sampling ratio of 4:1 and with the selected light readout using micropixel photodetectors satisfy the requirements of the CBM and MPD experiments. It has been shown that the length of the calorimeter module for the MPD setup can be reduced to 4 nuclear lengths without a significant deterioration of the energy resolution.

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References

[1] Guber F, et al., Technical Design Report for the CBM Projectile Spectator Detector (PSD), 2015, http://repository.gsi.de/record/109059/files/20150720_CBM_TDR_PSD.pdf

[2] http://mpd.jinr.ru/wp-content/uploads/2017/08/MPD_TDR_FHCal_v9_1.pdf

[3] Abgrall N, Golubeva M, Guber F, Ivashkin A et al., NA61/SHINE facility at the CERN SPS: beams and detector system, *JINST* **9** P06005, 2014.

[4] Golubeva M, Guber F, Ivashkin A et al., An Experimental Study of the Hadron Calorimeter Module Response to Protons and Pions with Energies of 1–5 GeV, *Instruments and Experimental Techniques*, 2014, **Vol. 57**, No. 6, pp. 651–657.